U.S. Army Corps of Engineers®

# HISTORICAL ORIGINS AND DEMOGRAPHIC AND GEOLOGICAL INFLUENCES

## *on Corps of Engineers Coastal Missions*

National Shoreline Management Study

IWR Report 04-NSMS-4

January 2004

# National Shoreline Management Study

The National Shoreline Management Study, authorized in the Water Resources Development Act of 1999 under Section 215c, presents an opportunity to examine the status of the Nation's shoreline for the first time in 30 years. Results from the study will provide a basis for Federal actions regarding shoreline management for the foreseeable future. The study will provide a technical basis and analytical information useful in developing recommendations regarding shoreline management, including a systems approach to sand management, and roles for Federal and non-Federal participation in shoreline management.

The study will:

- summarize information about the shoreline changes (erosion and accretion) available from existing data sources and examine the causes and economic and environmental effects;
- identify and describe the Federal, state and local government programs and resources related to shore restoration and nourishment; and,
- explore ideas concerning a systems approach to sand management.

The assessment of the nation's shorelines will take into account the regional diversity of geology, geomorphology, oceanography, ecology, commerce, and development patterns.

The study will be undertaken through collaborative efforts with other agencies. Information and products will be scoped, developed, and reviewed by national technical and policy committees involving multiple agencies. The National Study team will also solicit input from other interested parties and in developing study recommendations.

The U.S. Army Corps of Engineers' Institute for Water Resources (IWR) is managing the study working closely with the Engineer Research and Development Center Coastal and Hydraulics Laboratory and Corps field experts. National technical and policy committees, which include other agency experts, will be assembled as integral components of the study.

For further information on the National Shoreline Management Study, contact any of the following:

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Or go to the study website at: http://www.iwr.usace.army.mil/NSMS. The website provides reports to date and study progress along with topical links to other related studies and relevant agency programs.

A limited number of reports are available and may be ordered by writing Arlene Nurthen, IWR Publications, at the above Institute for Water Resources address, by e-mail at: Arlene.nurthen@usace.army.mil, or by fax 703-488-8171.

# HISTORICAL ORIGINS AND DEMOGRAPHIC AND GEOLOGIC INFLUENCES

## *on Corps of Engineers Coastal Missions*

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# Preface

This report was prepared as a product of the National Shoreline Management Study (NSMS). The NSMS, authorized by Section 215(C) of the Water Resources Development Act of 1999, is being managed by the U.S. Army Corps of Engineers' (Corps) Institute for Water Resources (IWR). This report serves as a companion to IWR Report 03-NSMS-1, *The Corps of Engineers and Shore Protection: History, Projects, Costs*, which focused on the shore protection mission. This report expands upon the previous report to examine the coastal mission, including navigation.

Finally, this report is partial response to the NSMS authorization, which, among other items, calls for a description of resources committed by Federal, State, and local governments to restore and renourish beaches, and recommendations regarding appropriate levels of Federal and non-Federal participation in shore protection. In order to respond to those study authorization items, one must understand the larger spectrum of agency involvement in coastal zones. This report provides a first response to those charges by examining part of the Corps historical involvement in the coastal zone. The NSMS will also examine other Corps activities as well as other agency contributions to the coastal zone in general, and in restoration and renourishment of beaches in particular.

# Acknowledgements

This report was prepared by Dr. Andrew Morang, of the Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL), and Mr. Charles B. Chesnutt, of Corps Headquarters. Direct supervision and support for this effort was provided by Dr. Robert Brumbaugh, (IWR), manager of the NSMS. Dr. Eugene Stakhiv is Chief of the Division, and Mr. Robert Pietrowsky is Director of IWR. Mr. Harry Shoudy provided Corps Headquarters oversight and direction to the NSMS.

This paper is updated from a presentation prepared by the authors for the Corps' Coastal Engineering Research Board meeting Honolulu, Hawaii, June 1999 (presentation by Chesnutt). The authors thank Dr. David Basco, Ms. Joan Pope, Mr. Theodore Hillyer, Ms. Lynn Martin, Dr. Robert Brumbaugh, and Mr. Harry Shoudy for reviewing the manuscript and providing helpful comments. T. J. Culliton of NOAA generously provided digital copies of population maps from his 1990 publication. Information on Corps shore protection projects comes from IWR Report 03-NSMS-1, *The Corps of Engineers and Shore Protection: History, Projects, Costs.*

# Executive Summary

The United States Army Corps of Engineers (Corps) has a complex mission in building and maintaining civil works projects along the coasts of the United States. This mission includes maintaining deep-draft and recreation navigation into harbors and inland waterways, building projects for coastal storm protection and flood damage reduction, and conducting environmental protection and restoration programs. These projects are based on or influenced by a number of factors, including:

(1) Historical settlement and development patterns;
(2) Geographical and geological conditions that vary regionally;
(3) Increasing pressures of a growing population along the coasts;
(4) Economic factors, such as the fundamental need to maintain navigable ports and waterways.

All demographic data point to the fact that the U.S. coastal population will continue to grow, and accordingly, that there will be continued demand for infrastructure improvement, storm protection, recreation development, and environmental restoration in the coastal zone.

This report for the National Shoreline Management Study (NSMS) does not address a relatively new Corps mission along U.S. coasts, that of environmental restoration, which can be undertaken using any one of several Congressional authorities. Nor does this study address another major Corps involvement along our coasts, regulation of filling of wetlands and other aquatic resources. Specifically, the Corps evaluates permit applications for filling the Nation's waters, including wetlands. Corps permits are also necessary for any work, including construction and dredging, in the Nation's navigable waters.

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# INTRODUCTION

The United States has always been a seafaring nation, depending heavily upon maritime commerce for its prosperity. During the 1600s and 1700s, the original colonies owed their prosperity largely to the availability of good natural harbors, rich nearby fishing grounds, and active trade with the Caribbean, Europe, and Africa. As the giant continent was explored and settled in the 1800's, rivers and the Great Lakes became the prime mode of moving goods and people to and from distant towns. Cities like New Orleans and New York became important commercial centers for trans-shipping goods from inland vessels to oceangoing ships and as points of entry for immigrants. In the 20$^{th}$ century, a new social phenomenon arose that resulted in an ever-increasing interest in the coast: more and more Americans achieved the economic means and leisure time to enjoy the beach for recreation. At the dawn of the 21st century, a growing number of people are moving to coastal areas, a trend that shows no sign of abating.

The prime Federal government agency responsible for maintenance of harbors and waterways is the Unites States Army Corps of Engineers (Corps). Until the 1820's, the Corps had minimal participation in nonmilitary coastal construction, but its responsibility for civil works projects increased greatly following a series of River and Harbor Acts, first enacted by Congress and signed into law by President Monroe in 1824 (Parkman 1978). Before World War II, the Corps mission in the coastal realm was largely restricted to constructing and maintaining harbors and river navigation systems. Since the war, the mission has expanded to include coastal storm protection, flood control, and environmental restoration. The Corps provides to the nation the knowledge, skills, tools, and managerial expertise necessary to conduct engineering activities along the coast.

The purposes of this report are to:

- Review the history of Corps participation in the coastal zone;
- Review geologic characteristics of U.S. coasts and explore how these have influenced coastal projects;
- Summarize types and locations of Corps of Engineers coastal projects – navigation and shore protection;
- Review demographic and economic trends and project future coastal activities.

This report does not address a relatively new Corps mission along U.S. coasts, that of environmental restoration, which can be undertaken using any one of several Congressional authorities. Nor does this study address another major Corps involvement along our coastline, regulation of filling of wetlands and other aquatic resources. Specifically, the Corps evaluates permit applications for filling the Nation's waters, including wetlands. Corps permits are also necessary for any work, including construction and dredging, in the Nation's navigable waters.

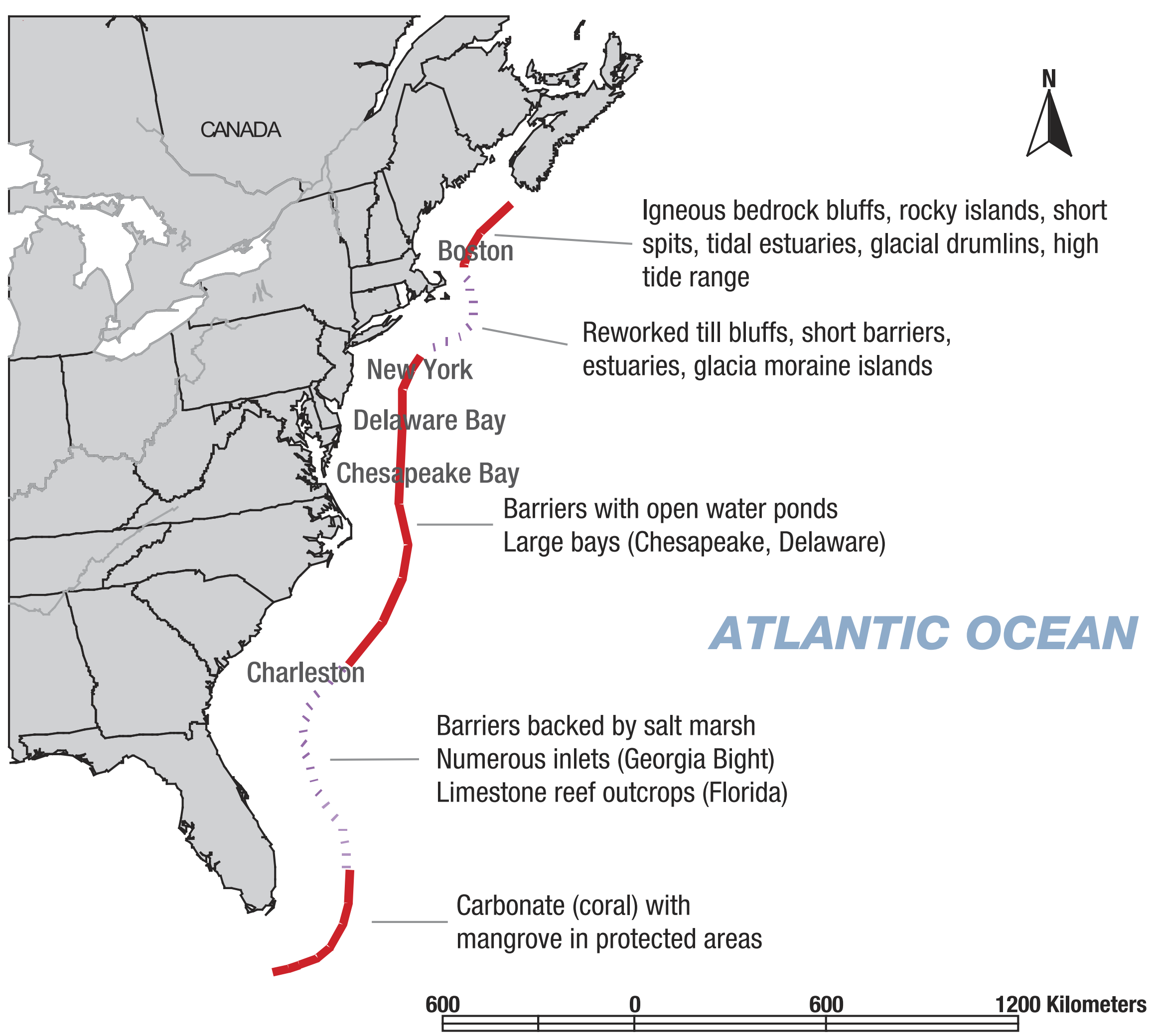
# GEOLOGIC INFLUENCES

The United States has a wide range of coastal environments, the result of continental tectonics, climate variations, sediment supply, and wave energy factors. These varying characteristics greatly affect the Corps' coastal mission and its construction and maintenance practices.

## Atlantic and Gulf Coasts

The Atlantic is a *trailing-edge coast*, the side of the continent that is moving away from the mid-ocean spreading center (Figure 1). The coast is characterized by a wide continental shelf and a low-gradient coastal plain (Inman and Nordstrom

**FIGURE 1 — Atlantic Coast characteristics**



1971). Little new sediment is being introduced to the coastal zone by rivers, and most sediment at the coast is reworked from relict beaches or offshore deposits. Along much of the east coast, sand is a valuable resource, and the Corps and state agencies are having increasing difficulty finding suitable sand for beach nourishment projects. The importance of the wide shelf is that hurricanes and northeasters can generate large storm surges. During a major storm, damage caused by waves is magnified greatly because the waves are superimposed on an elevated water level. Therefore, coastal engineers and planners have to design not just for wave heights but also for potential storm surge of elevated water levels that cause flood damage.

Greater than 17 percent of the North American coast is flanked by barriers (which include attached and detached spits, offshore barrier islands and bay-mouth bars), most facing the Atlantic Ocean and the Gulf of Mexico (Cromwell 1971). Table 1 lists the lengths of barriers and spits in the U. S. (also shown in Figure 2). The total length for the U.S. is 4,880 km, about half the North American total of 10,800 km computed by Cromwell. For more information, the most extensive survey of United States barriers is documented in the *Report to Congress: Coastal Barrier Resources System* (Coastal Barriers Study Group 1988).

Of the Atlantic states, Maine and New Hampshire have the fewest barriers because their coasts are largely composed of igneous rock (Figure 3). Massachusetts, with mostly glacial moraines and outwash along the coast, has the surprising total of 184 km of spits and barriers. Of the continental states, Florida has greatest length of barriers, 1,000 km for both the Atlantic and the Gulf shores. A portion of Florida's west coast, where wave energy is low, is mangrove swamp, but the Panhandle is famous for its glistening white beaches (Figure 4).

Almost 80 percent of the Texas shore consists of long barriers, which continue south into Mexico (Figure 5). Texas has one of the most erosive coasts in the United States, and 70 percent of the Gulf beaches are retreating at an average rate of 1.8 m/year and in some cases as much as 4.5 m/year (Moseley and Heilman 1999).

### Pacific Coast

The Pacific is a *leading-edge* (also called a *collision*) coast, the side of the continent that is moving towards an oceanic subduction zone. The coastal zone is characterized by a narrow or almost non-existent continental shelf, no coastal plain, and generally coarse sediments that come down from the mountains (Figure 6). Collision coasts are characterized by having a larger number of small streams of higher gradient than trailing-edge coasts in the same climate zone (Inman and Nordstrom 1971). The Pacific coastal range mountains are closer to the ocean than the Appalachians are to the Atlantic, with the result that the sediment grain size is not reduced as much during transport from the source area to the ocean. Because of the narrow shelf, some sediment eroded from beaches is lost to deep water via submarine canyons, and there are few offshore sand reservoirs that can be used for renourishment. The Pacific coast is exposed to a number of physical factors that contribute to shore erosion: winter storms, tsunamis, earthquakes, and sea level rise. These are significant hazards in southern California, where the bluffs are loosely-consolidated and are often unprotected by vegetation, and where houses are often perched at the very edge of the cliffs (Figure 7) (Fischer and Arredondo 1999). Retaining sand in the nearshore zone is a management and engineering challenge in a state where the beaches are a major tourist attraction and the pressure for housing and development is intense.

### Table 1: Barrier Islands and Spits of the United States

| Ocean or Sea | State | TotalLength (km)[1] |
|---|---|---|
| Atlantic | Maine | 11.4 |
| | New Hampshire | 2.5 |
| | Massachusetts [2] | 184.4 |
| | Rhode Island [3] | 17.6 |
| | New York [4] | 152.2 |
| | New Jersey | 106.0 |
| | Delaware [5] | 33.7 |
| | Maryland [5] | 49.2 |
| | Virginia [5] | 126.0 |
| | North Carolina | 380.7 |
| | South Carolina | 234.2 |
| | Georgia | 159.0 |
| | Florida | 533.3 |
| | **Atlantic Coast total** | **1,990** |
| Gulf of Mexico | Florida | 478.5 |
| | Alabama | 92.7 |
| | Mississippi | 59.5 |
| | Louisiana | 151.9 |
| | Texas | 498.0 |
| | **Gulf of Mexico total** | **1,281** |
| Pacific - Continental USA | Washington [6] | 63.9 |
| | Oregon | 91.9 |
| | California | 65.4 |
| | **Pacific total** | **221** |
| Beaufort, Chukchi, Bering Seas, Gulf of Alaska, Bristol Bay | Alaska total (incl. Aleutians) | **1,266** |
| Lakes Superior, Huron, Michigan, Ontario, Erie | Combined Great Lakes states | **124** |
| **United States total 2,3,4,5,6** | | **4,882** |
| North America [7] | | 10,765 |

Source: Unpublished data generated during the USACE's Barrier Island Sediment Study (BISS), 1989.

1 Length of barriers measured from U.S. Geological Survey topographic maps. Includes barriers and spits enclosing a body of water or marsh, not the total length of beaches in the United States. No data available for Puerto Rico, Virgin Islands, Pacific Trust Territories.

2 Includes Nantucket and Martha's Vineyard Islands.

3 Does not include spits in Narragansett Bay.

4 Atlantic Ocean only; does not include spits in Long Island Sound or Great Peconic Bay.

5 Does not include Chesapeake Bay.

6 Includes spits in Strait of Juan de Fuca. Does not include Long Beach Peninsula, enclosing Willapa Bay.

7 From Cromwell, 1971. Based on planimeter measurements of 1:$10^6$ scale operational charts.

**FIGURE 2 — Length of barrier islands and spits in the U.S. (kms)**
**For details, see Table 1**

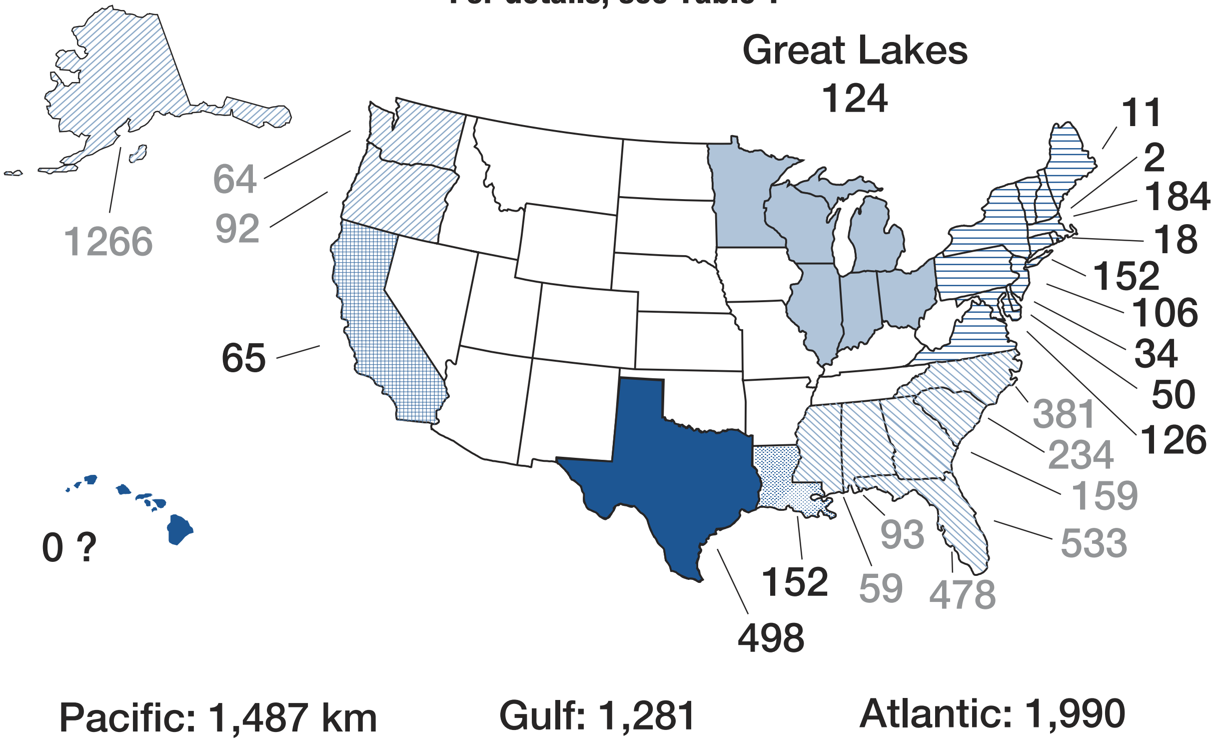



**FIGURE 3**— *Drowned glacial erosion coast: Maine (Potts Point, South Harpswell, near Brunswick, July 1994). Rock headlands and ridges run soughwest into the Gulf of Maine.*

**FIGURE 4**— *East Pass Inlet, Florida. View looking west towards Santa Rosa Island, with the Gulf of Mexico on the left and Choctawhatchee Bay to the right. The Barrier Island immediately beyond the inlet is part of Eglin Air Force base and has remained undeveloped. The Beach in the foreground is Holiday Isle, which has been heavily commercialized. This area of Florida is noted for its brilliant white quartz sand and excellent fishing. The inlet is a Federal navigation project with converging rubblemound jetties. Photograph taken March 1991.*

**FIGURE 5 — Gulf of Mexico characteristics**

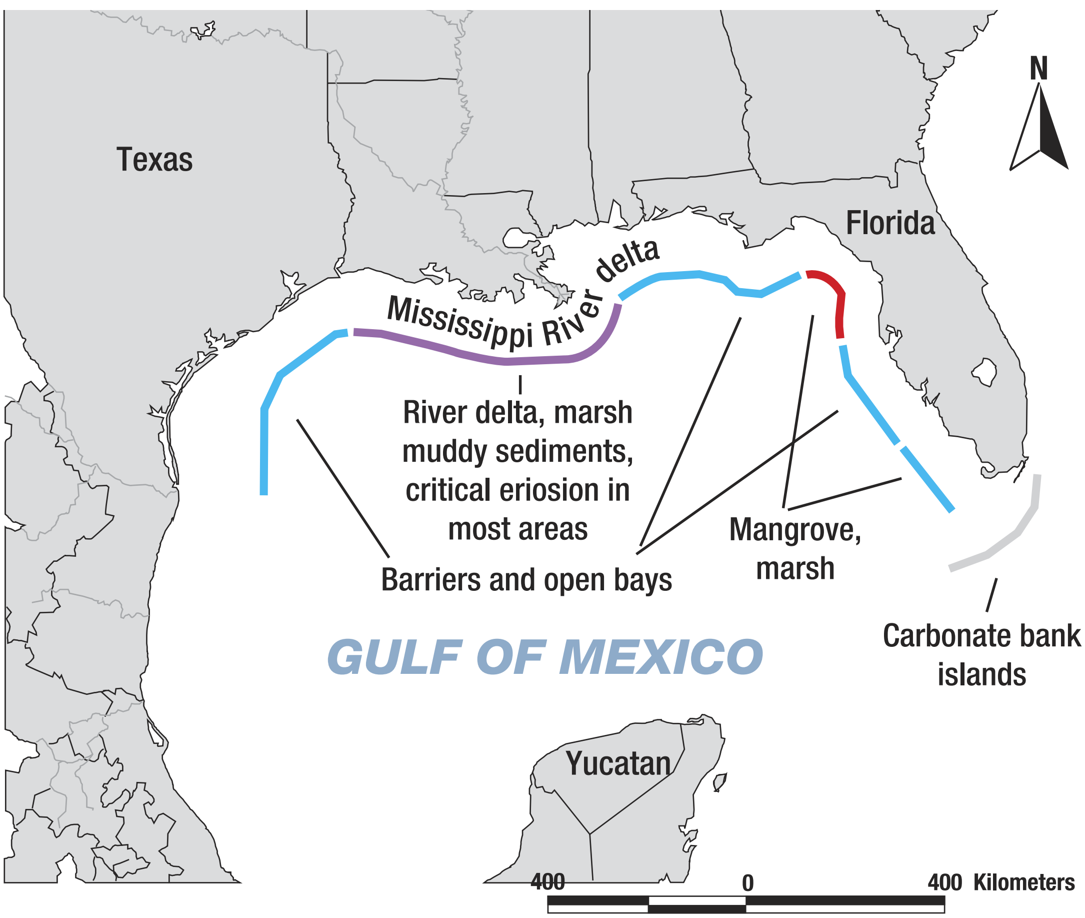


**FIGURE 6 — Pacific Coast features**

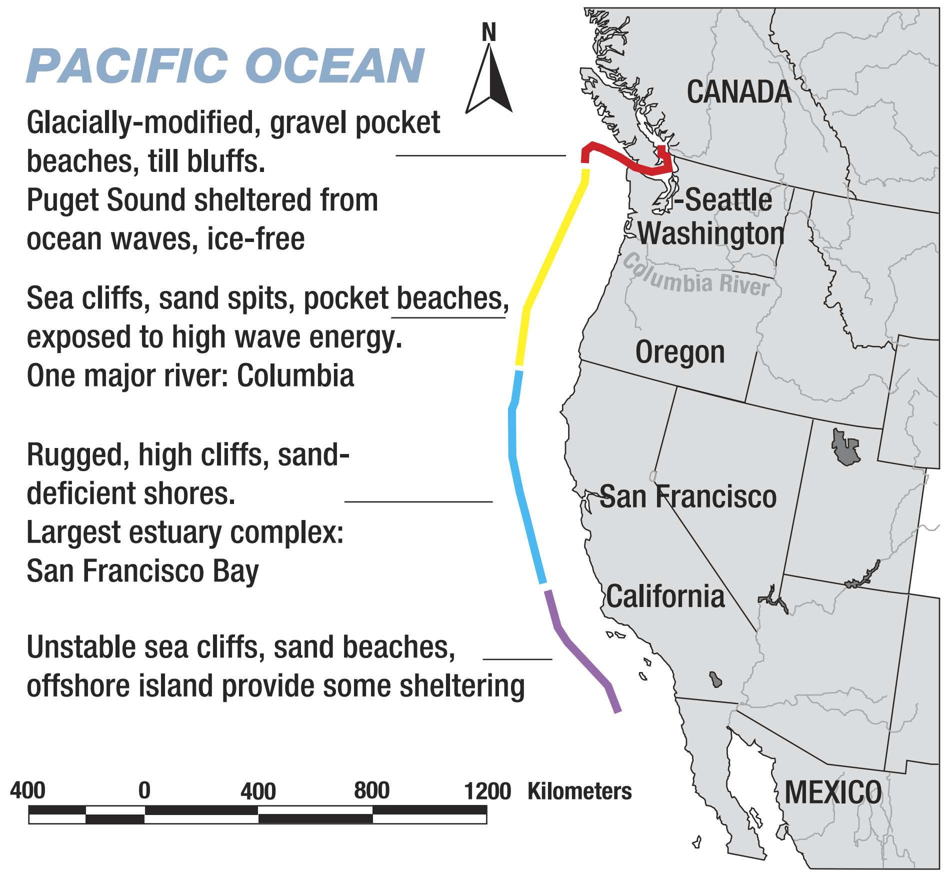
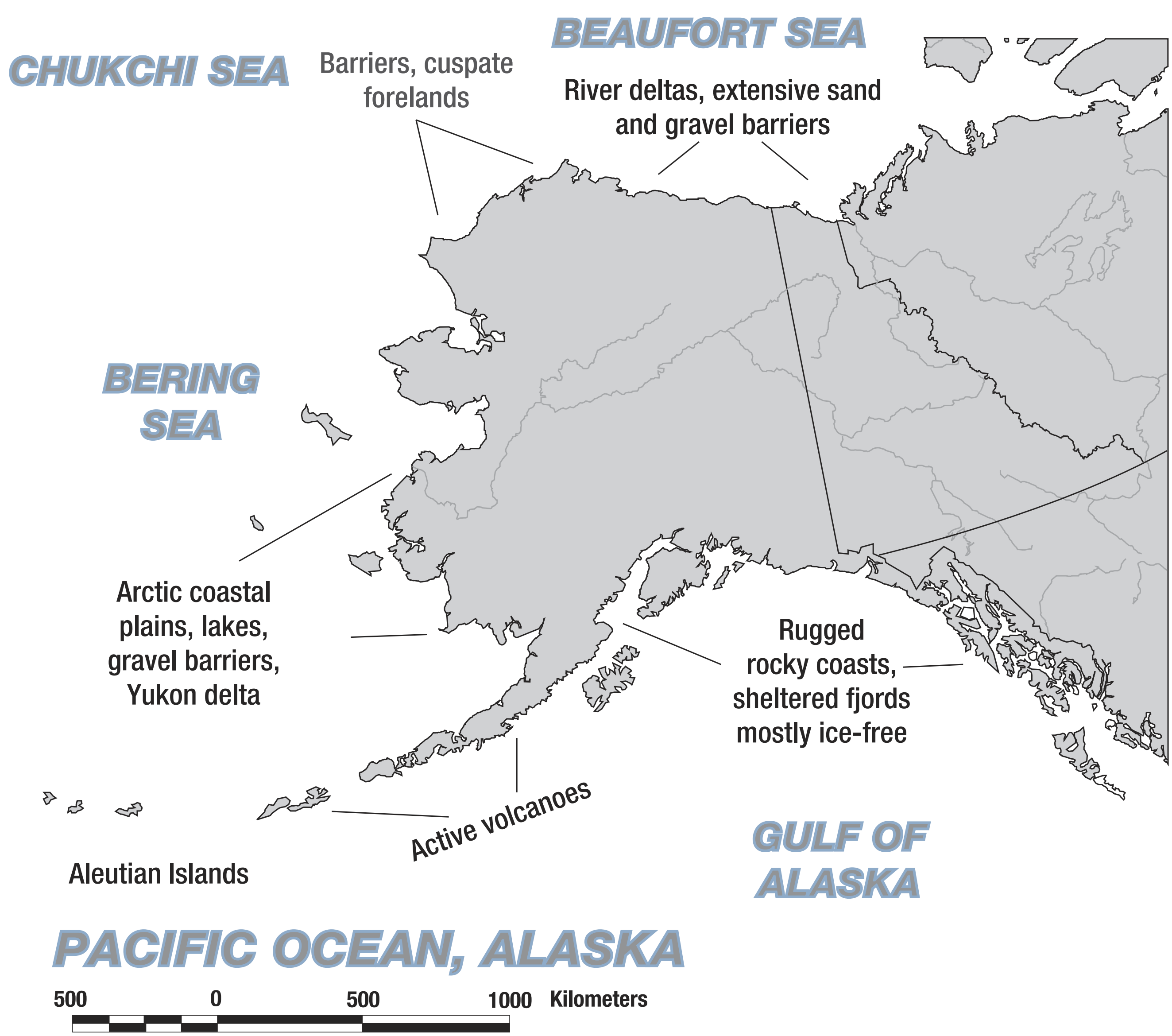



**FIGURE 7** — *Pocket beach just north of Laguna Beach, southern California (April 1993). Poorly-consolidated sandstone and conglomerate bluffs in this area are highly vulnerable to erosion, jeopardizing exclusive residential properties. Erosion is caused by storm waves, ground-water runoff, and piping, often contributed by landscaping efforts of cliff-top residents.*

California, Oregon, and Washington have few barriers, but an extensive barrier system is found on the Gulf of Alaska north of Bering Strait. Including numerous spits in the Aleutians and the Gulf of Alaska, the state of Alaska has almost 1,300 km of barrier islands and spits, exceeding Florida (Figure 8 and Table 1).

**FIGURE 8 — Rugged and complicated coast of Alaska**

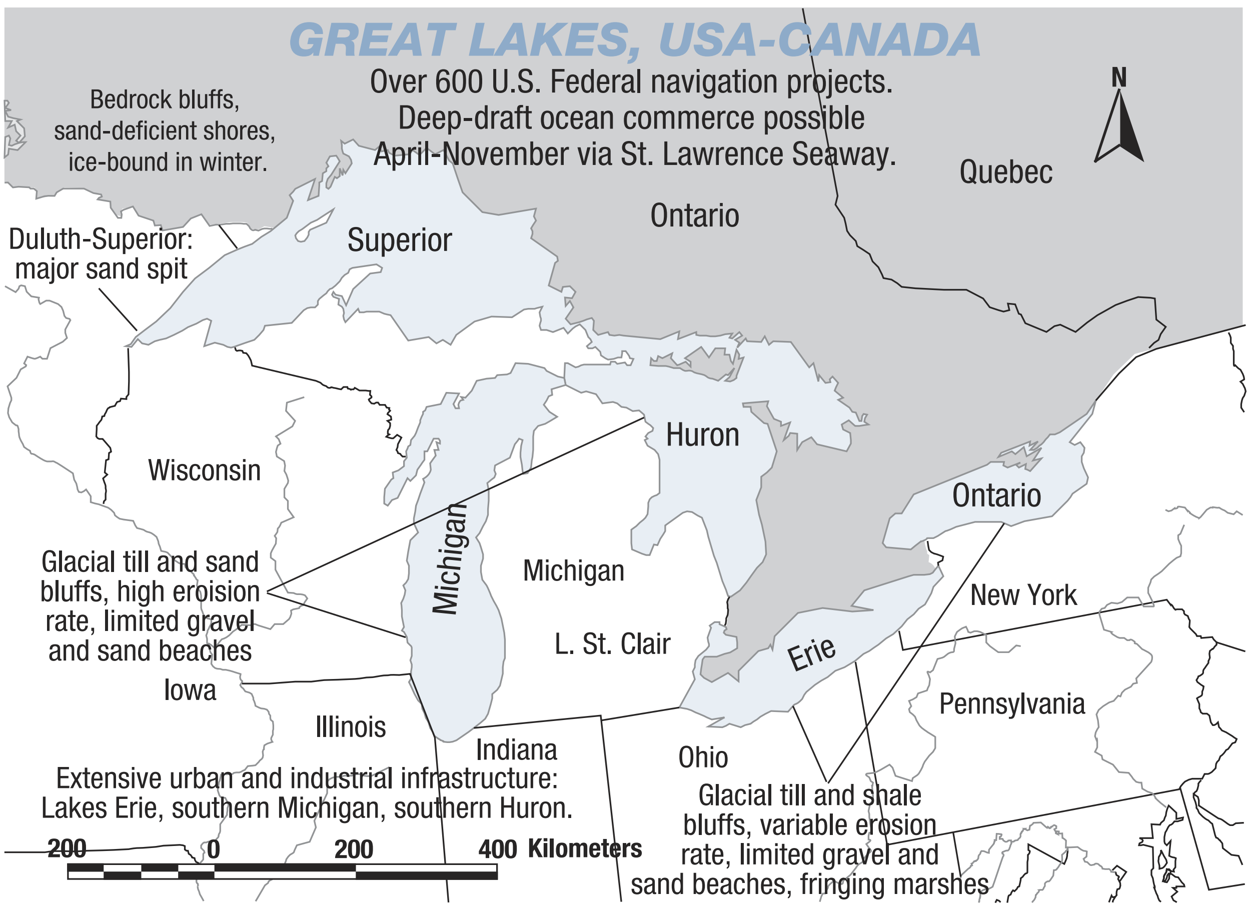



The Hawaiian Islands are rugged, basalt volcanoes projecting above the ocean surface. Because many of the mountainous areas of the islands are rugged and have poor soil, the coastal plains have been intensively developed. As a result, Hawaii's beaches and dunes have sustained massive human impact, causing sediment deficiencies that led to high erosion rates. The usual response was shoreline armoring, and Oahu and Maui are estimated to have lost between 20 and 30 percent of their beaches (Fletcher and Lemmo 1999).

## Great Lakes

The Pleistocene glaciers that formerly covered the upper Midwest extensively modified the geology of the Great Lakes region. Many reaches of Lakes Erie, Ontario, Michigan, and Huron consist of glacial till bluffs of varying sand, gravel, and clay content while portions of Lake Superior consist of erosion-resistant bedrock bluffs (Figure 9).

**FIGURE 9 — Great Lakes characteristics**



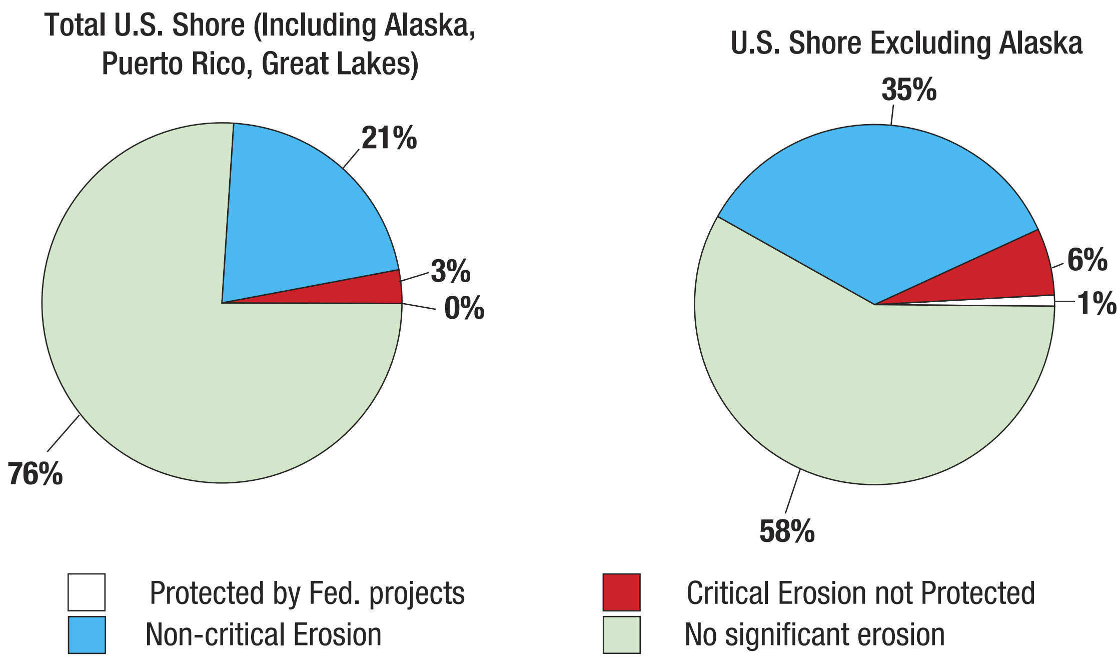

Before the industrial era, material eroded from bluffs and supplied by rivers remained in the littoral zone. When the first European settlers came to northern Ohio in 1796, the wide, continuous sandy beach of the lake was used as a road (Mather 1838). Today, most of the lakes are severely sand-starved compared to the conditions that existed 200 years ago, owing to a combination of geologic and development factors. Many of the bluffs bordering the Lakes have a limited sand content, and rivers over time have cut into their beds, reducing their gradient and carrying capacity. However settlement and industrialization may be more important. As the states developed and became urbanized after the mid-1800s, residents, industries, and municipalities attempted to arrest bluff erosion using various forms of structures and vegetation. Some of these protection measures worked temporarily, but they aggravated the erosion problem by reducing the supply of sediment that could be reworked and transported along the shore by waves. Equally important were the jetties built at many harbors to stabilize the navigation entrances. At most of these harbors, sand accumulated in the fillets and navigation channels, from whence it was disposed in deep water, thereby further depriving the littoral system of sediment.

The Great Lakes shores are fundamentally different from ocean shores in a number of ways. Four of these factors affect Corps project design and management. First, the water is fresh, making the biological habitat very different than ocean coasts, and requiring different expertise for wetland restoration and management. Second, there is no periodic tide, but seiching occurs on irregular basis depending on wind conditions and ice cover. Third, average water levels vary seasonally and on cycles of years due to hydrologic conditions (annual rainfall, cloudiness, ice cover, temperature), as opposed to ocean coasts, where sea level change is usually noticeable only over periods of decades or centuries (Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data 1992; Great Lakes Commission 1986). Varying water level has a fundamental influence on the portion of the shoreface that is exposed to wave energy and the exposure of bluffs to wave attack (Hands 1984). Fourth, short fetches produce erosive wave conditions during storms (short-period, steep waves), but there are limited long-period swell waves to naturally rebuild beaches during calm conditions.

## Erosion

Coasts are dynamic, and erosion and accretion are natural processes, although altered by human activities and structures. Coastal erosion is obviously a major problem throughout the United States, but it is difficult to compile reliable statistics. The most comprehensive evaluation of shoreline characteristics was the National Shoreline Study of 1968-1973, authorized by Congress and conducted by Corps districts for all states (U.S. Congress, House 1973). This study tabulated 135,500 km (approximately 84,200 miles) of ocean, estuarine, and Great Lakes shoreline, including Alaska, Hawaii, Puerto Rico, and the Virgin Islands (U.S. Congress, House 1973, Table 1). Of this total, 33,000 km (20,500 miles) were identified as undergoing significant erosion, or about 25% of the nation's shores. Excluding Alaska, for which there was relatively scant development as well as information along the coast, approximately 42% of the nation's shores were identified as undergoing significant erosion. Significant erosion was divided into critical and non-critical areas, with critical being defined as "those areas where erosion presents a serious problem because the rate of erosion considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors, indicates that action to halt such erosion might be justified." Some 4,300 km (2,700 miles) were in the critical category, of which only 364 km were protected by Federal projects at that time (Figure 10).

**FIGURE 10 — Percent U.S. Shoreline Experiencing Erosion, 1971**
(Source: U.S. Congress, House, 1973).




Length of total U.S. shore: 135,500 km
Length of shore excluding Alaska: 59,400 km
Length of federally-protected shore (1971 data): 364 km

Total Coasts included ocean, estuarine and Great lakes shorelines-
all areas that might suffer wave erosion.

Many social and demographic conditions have changed drastically since the statistics listed above were computed. For example, many coastal areas, especially in Florida and California, and most of our barrier islands have been developed extensively since the 1970's. In the last three decades, the public's perception and recognition of the value of beaches, wetlands, and estuaries has changed greatly. Congress has recognized the need to update these statistics by authorizing the National Shoreline Management Study, under Section 215(c) of the Water Resources Development Act of 1999 for which this report was prepared.

# COASTAL PROJECTS OVER TIME

## Navigation

Deep-draft and inland waterways are critical to the commerce of the United States, and maintaining the nation's deep-draft navigable waterways is one of the Corps' oldest missions. Dredging of waterways and ports and protection of those facilities against waves and shoaling are important to waterway and port viability.

### *Dredging of Waterways and Ports*

In Fiscal Year (FY) 2000, Corps and contractor dredges removed 218 million $m^3$ (285 million $yd^3$) of material from Federally constructed and maintained channels at a cost of \$821.6 million. These values are for both inland and coastal Federal projects. Maintenance dredging accounted for almost 80 percent of the quantity and 66 percent of the cost. The average cost for maintenance dredging was \$3.13/$m^3$ (\$2.39/$yd^3$), while the average cost for new work (i.e., opening new or enlarging existing channels) was \$6.26/$m^3$ (\$4.79/$yd^3$) (Navigation Data Center 2001). As another example of the scale of these efforts, Louisiana alone has more than 3,200 km of channels maintained by the Corps.

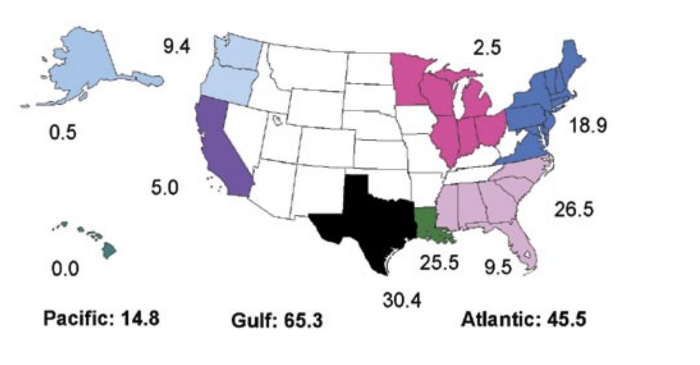



**FIGURE 11** — *Fiscal Year 2000 dredging by Corps of Engineers divisions at Federally maintained harbors around the U.S. (million cubic meters). Note: the New Orleans District has the single greatest dredging volume of all the Corps Districts.*

Dredging in the coastal zone is the largest single item in the Corps' budget because more than 90 percent of the Nation's top 50 ports for foreign commerce require regular dredging. Out of 30 Districts with navigation projects in the United States, 20 must dredge to support deep-draft navigation. In 2000, the Corps dredged via contract or federal-owned plant 15 million $m^3$ from Pacific ports, 65 from the Gulf of Mexico, 46 from the Atlantic, and 2.5 from the Great Lakes (Figure 11; statistics from the Navigation Data Center). These volumes are from coastal sites only and do not include inland river waterways, but they include waterways like the Great Lakes and the Mississippi River as far as Baton Rouge because they are maintained for oceangoing vessels. Another 70 million $m^3$ is dredged from berths and private terminals by various harbor authorities.

Petroleum was the major commodity at all these ports, even New York. Table 2 lists the top ten U.S. ports in terms of total tonnage. Note that most are in the Texas/Louisiana region, underscoring the importance of the Gulf of Mexico to our economy (Figure 12). Petroleum imports have increased from 310,000 million barrels (mb) in 1950 to 4,182,000 mb in 2001, more than a tenfold increase (Energy Information Administration 2002). Considering the American lifestyle, the construction of larger homes, the rapid increase of immigration, and the use of ever-larger and fewer fuel-efficient vehicles, there is almost no likelihood that our energy use will decrease in the foreseeable future. As petroleum

**Table 2: Leading U.S. Foreign Trade Ports in Terms of Tonnage, 2000**

| Port | Domestic Trade (million short tons) | Foreign Trade (million short tons) | Combined (million short tons) |
|---|---|---|---|
| Port of South Louisiana | 119.1 | 96.8 | 215.9 |
| Houston, Texas | 62.6 | 24.0 | 186.6 |
| New York (New York and New Jersey) | 72.3 | 64.9 | 137.2 |
| New Orleans, Louisiana | 38.3 | 51.7 | 90.0 |
| Corpus Christi, Texas | 24.0 | 57.3 | 81.3 |
| Beaumont, Texas | 16.0 | 60.9 | 76.9 |
| Long Beach, California | 17.4 | 52.5 | 69.9 |
| Baton Rouge, Louisiana | 42.5 | 22.7 | 65.2 |
| Port of Plaquemines, Louisiana | 38.9 | 20.8 | 59.7 |
| Texas City, Texas | 20.3 | 37.8 | 58.1 |

*Notes:*
1. Source: Navigation Data Center 2001 (data revised 4 Nov 2002)
2. The 7th highest tonnage port in the U.S. is Huntington, West Virginia/Ohio/Kentucky with 76.9 million total short tons, all of which is domestic commerce.

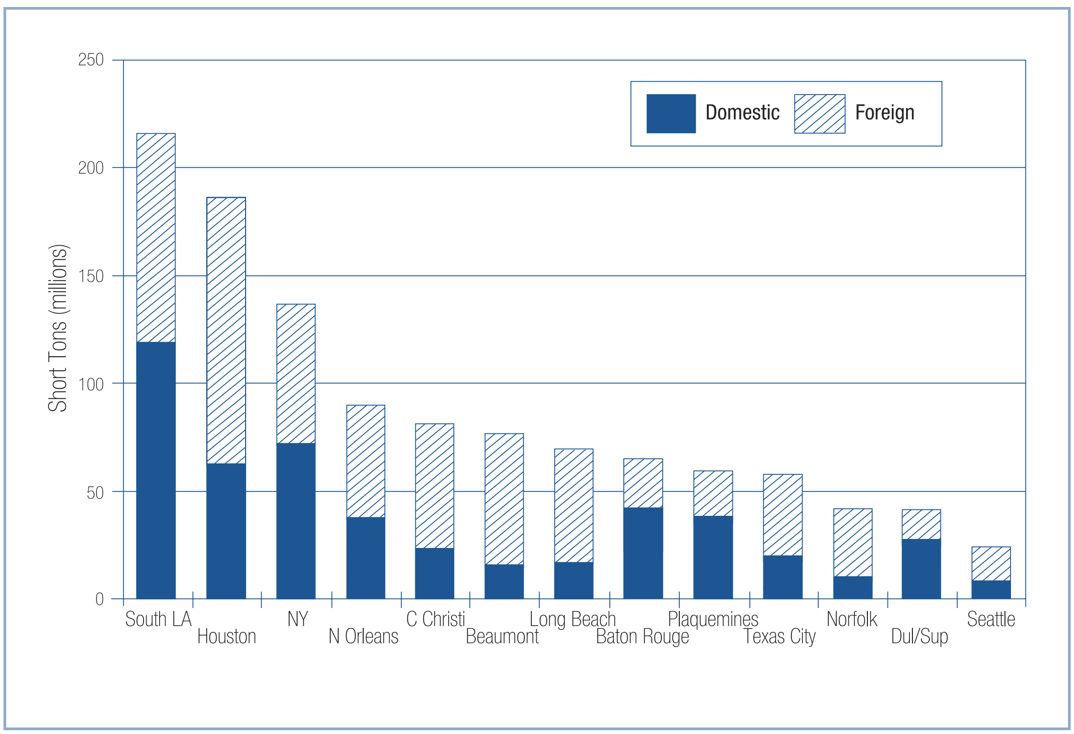



**FIGURE 12** — *Waterborne tonnage of selected U.S. ports in 2000. Petroleum products dominate the Gulf of Mexico ports. Baton Rouge is classified as a seaport because ocean-going vessels can reach it via the Mississippi River.*

consumption increases, shipments will increase, in turn requiring more navigation and infrastructure improvements in the Gulf ports, including dredging.

With changes in technology and commercial trends, U.S. ports are experiencing a major shift in the way they are operated, what they are used for, and the way they are perceived. Because of technological changes in the way cargo is transported and increased costs of port operations, some smaller ports can no longer compete with larger ports situated in more geographically advantageous regions (Levebre 1999). Declining fish stocks have greatly reduced the number and size of fishing fleets in New England and the Pacific Northwest, resulting in reduced demand for related support services. In the Pacific Northwest, many smaller harbors that prospered up through the 1970's by servicing the timber trade are now scrambling to find alternate cargoes. While some small ports may not survive these radical changes, others are reviving by shifting toward water-dependent activities such as whale-watching, sport-fishing, and recreational boating. Some large ports have adapted very successfully. For example, the Port of Seattle is thriving because of its advantageous situation in Puget Sound—the proximity of industry, and good rail connections that bring grain, oilseeds, and other agricultural commodities right to the docks. With increasing sales to Pacific Rim countries, Seattle is becoming one of the major grain exporters of the United States.

### *Breakwaters and jetties*

Most harbors and inlets with commercial navigation in the United States are protected and stabilized with hard structures, such as jetties and breakwaters.[1] Many of these were built by the Corps or adopted as Federal Projects after the government assumed responsibility for state and local projects. Table 3 and Figure 13 summarize statistics for Federal projects.

The character of navigation projects and facilities varies among the four regions of the USA. On the

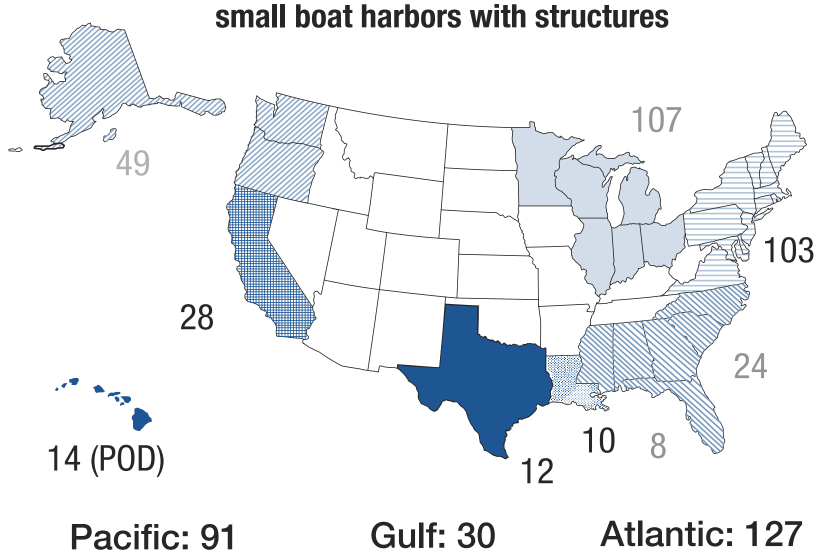
**Table 3: Corps of Engineers Jeffies and Breakwaters, 1986**

| Region | No. of Harbors with Structures | Total Length of Structures, km | Characteristics |
|---|---|---|---|
| Atlantic | 131 | 75 | Typically rubblemound, used to stabilize inlets |
| Gulf of Mexico | 30 | 119 | Stabilize inlets and reduce shoaling |
| Pacific | 91 | 130 | Large structures, difficult and expensive maintenance because of high wave energy |
| Great Lakes | 107 | 131 | Great variety of construction methods; many projects more than 100 years old and in need of rehabilitation. Subject to ice damage and varying water levels. |

Source: U.S. Army Corps of Engineers (1986), Tables D-1, D-2, D-3, and D-4

[1] Jetties are structures extending out into bodies of water designed to prevent shoaling of channels by littoral materials. Breakwaters are structures that protect a shore area, anchorage, or basin from waves. (USACE 2002).

**FIGURE 13 — Federally-maintained deep draft and small boat harbors with structures**




Great Lakes, a variety of construction methods were used to build jetties, including sheet pile, wood cribs, concrete wall, and stone rubblemound. Many of these projects, built in the early-mid 1800's as the upper mid-West experienced an industrial and economic boom, are in serious need of rehabilitation (Pope 1992). But, rebuilding will be difficult and costly, and priorities will have to be based on current shipping needs as well as predicted economic trends. For example, some Lake Erie ports no longer service the bulk shipping that figured so prominently in their economies as recently as the 1970's. Today, with improved water quality, fishing is becoming a much more important part of the economy, and fishing vessels need different infrastructure and port facilities than bulk cargo ships.

On the Atlantic Coast, most inlets with navigation channels have been stabilized with structures. Typically, mechanical bypassing is needed to mitigate the interruption of littorally-transported sediment. In the past, the Corps cost calculations and, therefore, maintenance practices, were primarily directed toward maintaining navigation channels and driven mainly by cost effectiveness relative to maintaining individual projects. However, in the future, the Corps will be attempting to manage sediment on a regional basis rather than project-by-project, and the combined recreational, environmental, and flood-control benefits of sediment bypassing will become as significant to the economic justification of projects as are the navigation aspects alone. Therefore, it is likely that the Corps will become much more involved in active sediment bypassing to insure that sand remains in the littoral zone.

The largest coastal structures are along the Pacific coast because this is our highest-energy coast with the most destructive wave energy. One of the Corps' biggest challenges is maintaining stability and integrity of jetties and breakwaters, which are difficult and costly to repair. Most of the Pacific jetties were originally built from the land out to sea, using railroad-mounted cranes that operated from a railroad trestle along the top of the structures. Even then, wave conditions were a major limitation, and at Grays Harbor, a locomotive was picked up by storm waves and dumped into the ocean. Today, the trestles and track infrastructure are gone, so when repairs are necessary, the contractor has to build a road along the top of the existing jetty or attempt a high-risk water-borne operation. The road is often one of the most expensive aspects of a jetty project. If the work is not completed in one season, the road is usually washed away during the winter and has to be rebuilt the next spring. The dimensions of the jetty are not necessarily based on oceanographic criteria but rather by the dimensions of the roadway and the height needed to keep the equipment and workmen safe from waves.

### *Shore Development, Protection, and Beach Erosion Restoration - Historical Perspective*

Before the 20th century, America's barrier island shores were largely undeveloped. Some barriers were exploited for natural resources, and evidence indicates that as soon as settlers arrived in the New World, they damaged dune vegetation (Goldsmith 1985). In the 1600's, settlers harvested timber from once-stable, forest-covered dunes, and New Englanders grazed their cattle on salt marshes and beaches. On Cape Cod, following the war of independence, large areas of dune and beach were flattened to make space for salt-evaporation vats. The United States had lost some of its pre-war suppliers of salt, and an investment in salt vats on Cape Cod yielded a handsome return. "Most stretches of virgin beach and upland dune, land considered useless until then, were becoming marred with windmills, pipes, and huge vats with rolling roofs. The prices were high, and the market seemed endless."h (Kurlansky, 2002, p.239).

Despite limited economic exploitation of barrier islands, towns were usually located on estuaries or bays, seldom on the open coast except for fishermen's villages. Few Americans had the time, money, or interest to vacation at the beach. However, earlier societies in other parts of the globe did have such an interest. In Europe, the Romans introduced to the world the concept of the holiday at the coast. From the end of the republic to the middle of the second century of the empire, resorts thrived along the shores of Latium and Capania, and an unbroken string of villas extended along the coast, from the seashore near Rome to the white cliffs of Terracina. Fine roads connected these resorts to the capital, allowing both the well-to-do and the masses to descend from sultry and vapor-ridden Rome to the sea. After a long hiatus, the beach became popular again in the 1800's in northern Europe. Prosperity and the development of railroads allowed city dwellers in England, France and the Low Countries to conveniently visit the shore, at first for medical therapeutic reasons, and later, as the century progressed, for social and recreational reasons. By mid-century, being seen at one of the fashionable beach resorts had become *de rigeur* for both the elite and the *nouveau riche* (Lenček and Bosker 1998).

In America, resorts developed on the Atlantic seaboard. In the 1890's Coney Island became famous (or infamous) for its gambling, high life, and bawdy entertainment palaces. However, for the most part, the barrier islands remained undeveloped. Before the 20th century, most Americans toiled incessantly, relatively few knew how to swim, and exposing bare skin to the sun, especially in mixed-sex company, was morally unacceptable. Barrier islands were harsh environments, with undependable fresh water, insects, difficult access, and barren soil. As a result, little effort was devoted to coastal science in the United States, while Italy, Holland and China already had centuries of experience with building dykes to keep the sea out of low-lying regions. The Romans discovered and developed many engineering concepts and methods to protect coasts, but these were lost after the fall of the Empire (Franco 1996; Bijker 1996).

In the U.S., interest in shore protection began in New York, New Jersey, and Texas during the last decades of the 19th century and the early part of the 20th as a result of social, demographic, and natural factors. Galveston, Texas, was inundated and more than 6,000 people were killed by the devastating hurricane of 1900 (Larson 1999; Rappaport and Fernandez-Partagas 1995). As a response, the city built a 5,400-m seawall and elevated the island by pumping sand (some reports state more than 12 million $m^3$) from Galveston Bay. Additionally, Congress authorized the Corps to build a connecting seawall to protect nearby Fort Crockett (Alperin 1977).

On the Atlantic seaboard, the New Jersey shore and Long Island, which were within easy reach of the growing populations of New York City and Philadelphia, experienced intense and uncontrolled development, especially during the economic boom following World War I. The technical revolution brought trains, automobiles, gasoline-powered pleasure boats, labor-saving devices for the home, and a new era of leisure to a prospering nation (U.S. Congress, House 1973; Morison and Commager 1962). Electricity provided convenient power to energy-poor barriers. Engineers piped fresh water from the mainland or tapped aquifers. Changing morals allowed people to sunbathe, and new elastic fabrics allowed designers to create more attractive swim wear while they simultaneously diminished the size of the garments (Lenček and Bosker 1998). Bootlegging was a growth industry for many remote barrier island towns during the Prohibition years of 1920 to 1933 (*e.g.*, see Talese 1992). And with the growing use of the automobile, beach-goers in increasing numbers followed newly-built roads to the coast.

During this era of unchecked construction, dunes were destroyed to make way for hotels, boardwalks, roads, and houses. Breakwaters and jetties were built to aide large and small craft navigation. For jetties built along uninhabited coastal areas in the 19th and early 20th centuries, the build up of sand on the up-drift beach and the loss of sand from the down-drift side was considered a minor consequence to obtaining the benefits of ocean navigation. In nearly every instance, these structures interrupted the alongshore movement of sand and starved downdrift beaches (U.S. Congress, House 1973), but it was not until the shore became more developed in the later 20th century that the interruption of sand transport was recognized as a problem. Natural factors were also at work: during the period 1915 to 1921, three hurricanes and four tropical storms battered the Jersey shore, causing severe beach erosion. In New Jersey, millions of dollars were spent on uncoordinated and often totally inappropriate erosion control structures, which often produced results that were only minimally effective, and, in some cases, were counterproductive (Hillyer 1996). Engineers and city managers soon realized that individual property owners were incapable of dealing with coastal erosion and that a more comprehensive approach was necessary.

In contrast, some of the early large-scale coastal projects undertaken by state and city governments proved to be remarkably successful social and engineering accomplishments. Starting in 1904, with the erection of a dance pavilion on a marshy, mosquito-infested spit of land, local developers began to enhance the appeal of the ocean coast of Biscane Bay in southeast Florida. In 20 years, Miami Beach was totally reshaped and turned into one of America's premier vacation destinations, in turn becoming some of America's most valuable real estate. "Rivaling the Egyptian pyramids in scope, engineering, and the sheer numbers of its builders, Miami Beach was a living monument to modern America's passion for instant gratification" (Lenček and Bosker 1998, p. 240). During this same period, Henry Flagler similarly dredged canals, filled in swamps, and reshaped Palm Beach, molding it into a Mediterranean-style venue of pleasure for the "fast" set.

America's first large engineered beach fill was the boardwalk and recreational beach on Coney Island in 1922 - 1923 (Farley 1923). With the completion of the project, immigrants and factory workers could escape the sweatshops of the sweltering city and enjoy

CONEY ISLAND – 1941

**FIGURE 14** — *Coney Island, New York, on a hot summer day in 1941. As war engulfed Europe and China, New Yorkers tried to enjoy relief from the summer heat. Groins seen in the background were part of the original design of the recreational beach. Coney Island is now maintained by the Corps of Engineers and has been recently renourished. Photograph from Beach Erosion Board archives.*

a (crowded) Sunday at the beach for only a nickel subway ride (Figure 14; Dornhelm 1995). This was followed by the ambitious construction of the Jones Beach Parkway by Robert Moses and the Long Island State Park Commission in 1926 - 1929, during which more than 30 million $m^3$ of sand was pumped to create Jones Island (DeWan 1998; Kana 1999). In Chicago, the entire waterfront was reshaped between 1920 and 1940 with the addition of more than 14.2 square km of fill, resulting in one of America's premier urban parks (Chrzastowski 1999). These were city- and state-sponsored projects, with minimal involvement by the Federal government.

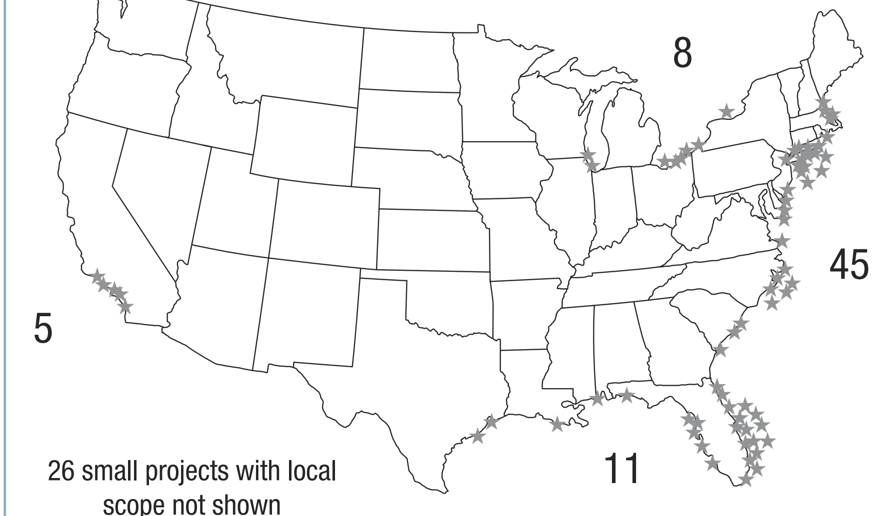
The Federal Government's role in shore protection began in the 1930's in response to the growing recognition that haphazard and uncoordinated shore protection measures and poorly-designed hard structures were ineffective, ugly, and damaging to the environment. In addition, 13 serious hurricanes between 1921 and 1930 caused great damage and almost 2,000 deaths. In 1930, Congress passed Public Law (PL) 71-520 (Rivers and Harbors Act of 1930), which authorized the Corps to study (but not construct) shore protection measures in conjunction with local governments. Congress also established the Beach Erosion Board, which in 1963 became the Corps' Coastal Engineering Research Center. During the 1930's, ten major hurricanes struck the coastal states. Two of these rank among the most severe in terms of death in the nation's history: the "Labor Day" storm of 1935 devastated southern Florida, killing 408 people, while the Great New England Hurricane of 1938 inundated communities in Long Island, Connecticut and Rhode Island, including New London and Providence, killing over 600 people (Clowes 1939; Allen 1976; Minsinger 1988). The Federal involvement in shore protection throughout the 1930's was mostly limited to planning studies and technical advisory services and research. These planning efforts were cost-shared between the Federal and local governments.

The most common practice to reduce erosion up through the 1940's was construction of hard structures such as groins, jetties, and seawalls (Committee on Beach Nourishment and Protection 1995). Atlantic City, Miami Beach, Ocean City, and many towns on the New Jersey shore constructed extensive groin fields.[2] This approach was reasonably successful at the time because the coast was not as extensively developed as it is now. Hard protection along a short portion of the shore typically moved the erosion problem downdrift, but this effect was not fully understood then, nor was it viewed as significant if the threatened area was undeveloped.

[2] Groins are narrow structures, extending out into bodies of water to reduce long shore currents, and/or trap and retain littoral material. Most groins extend from a seawall or the backshore (USACE 2002)

Shore protection research was interrupted in World War II as the Corps of Engineers committed its resources fully to the war effort (Beck et al. 1985). However, many advances in wave hindcasting, oceanography, and coastal engineering that came about as a result of wartime research were later applied to civil projects (Wiegel 1999; Wiegel and Saville 1996).

**FIGURE 15 — Corps shore protection and beach erosion control projects (Source: Hillyer 2003).**




Following the war, the Corps' coastal protection mission expanded through a series of 20 legislative acts. For example, PL 84-71 in 1955 directed Federal agencies to develop shore protection measures. In 1956, PL 84-826 defined periodic renourishment as "construction" for the protection of shores. PL 84-826 also authorized Federal participation in shore protection and restoration on private property. Previously, in 1946, PL 79-526 authorized Federal participation only in the cost of protecting of publicly-owned shores. Following Hurricanes Donna (1960) and Carla (1961), PL 87-874 increased the Federal share from 33 to 100 percent for shore protection study costs. The change from cost-shared to 100 percent Federally-funded shore protection and erosion control studies, coupled with the need to provide protection in the areas damaged by the 1950s and 1960s hurricanes resulted in a large number of studies and subsequent project authorizations. A number of Corps projects originated with the attempts to repair damage from the infamous Ash Wednesday Storm of 6-8 March 1962. It claimed 33

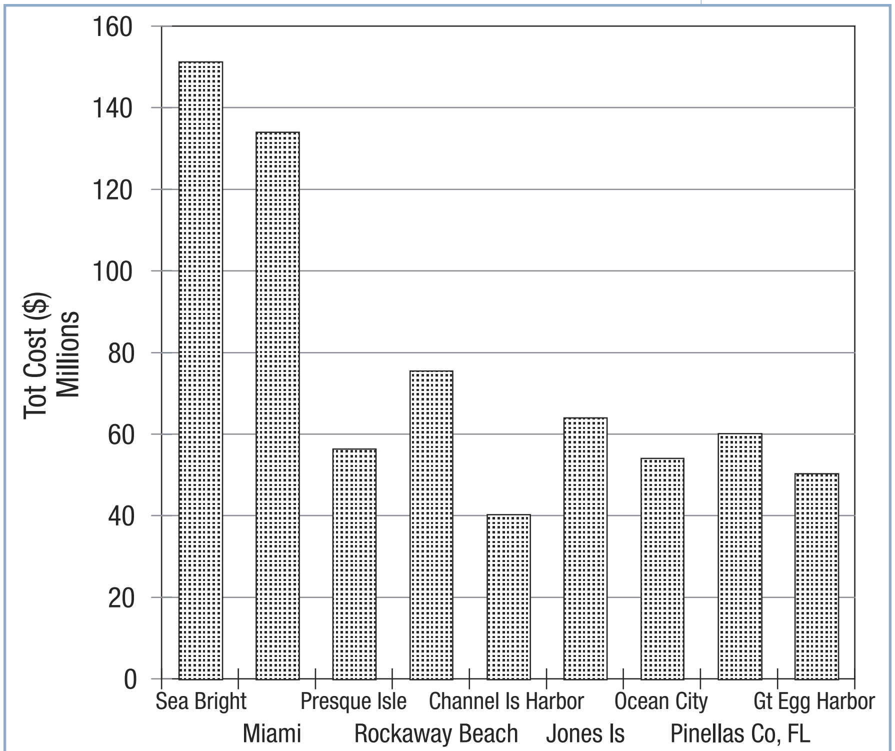



**FIGURE 16** — *Total expenditures for initial construction, structures, and renourishments for the largest Corps shore protection and restoration projects (Hillyer 1996). Values have not been adjusted for inflation or recomputed to reflect current cost of sand. Sea Bright, still in progress, shows initial construction cost only. The total volume of fill over the 42-km reach at Sea Bright is estimated to be about 19 million m3. Periodic renourishment, each six or seven years, is estimated to cost $35 million (data from Corps New York District).*

lives, caused great property damage in Delaware, New Jersey, and New York, and cut numerous new channels across the New Jersey and Long Island barrier, some of which had to be closed with dredged material. PL 94-587 (1976) authorized the placement of sand from dredging of navigation projects on adjacent beaches, with the increased cost paid for by non-Federal interests. Section 111 of the River and Harbor Act of 1968 authorized the Corps to mitigate erosion and damage that result from Federal navigation works. Particularly in the Great Lakes, Section 111 authority has been used to fund coastal processes studies, some of which have resulted in modifications to the way channels are dredged and the material disposed. The Water Resources Development Act of 1986 was a legislative landmark because of numerous beneficiary-pay reforms that made local sponsors active participants in the development and implementation of coastal projects.

As a result of these legislative changes and a growing perception among the public that erosion control was beneficial to economic development, a number of shore protection projects were authorized and constructed by the Corps around the country (Figure 15). Of 97 total authorized shore protection projects, 71 are classified as large, having an average total actual cost of $17 million (Hillyer, 2003). The Miami Beach project, formerly the largest shore protection and beach erosion control effort in the United States, has cost through June 2002 about $134 million. It has been surpassed by the Sea Bright project, now underway along a 42-km stretch of the New Jersey shore and estimated to cost more than $150 million for construction alone (Figure 16). Valverde, Trembanis, and Pilkey (1999) tabulated that 270 million $m^3$ of sand have been deposited on U. S. east coast barrier beaches since 1923 at 154 locations, of which about 65 percent was placed by federally-sponsored projects. This included both storm and erosion-control projects and navigation projects with beach disposal of dredged material. Hillyer (1996) estimated that 110 million $yd^3$ ($85m^3$) had been placed at 49 of 56 Corps projects through 1993. These statistics give an idea of the magnitude of beach fill during the 20$^{th}$ century.

Presently, the Corps places sand on beaches via two types of activities: specific shore protection projects and in conjunction with navigation dredging. Shore protection projects are the result of Congressional authorizations that involve lengthy planning, design, construction, and monitoring elements. Compared to alternatives such as hard structures, the Corps considers that periodic nourishment is usually the most cost-effective way to reduce the threat of coastal storm damage and avoid the costs of exceptional storms. There have been strong criticisms in the popular press (Pilkey and Dixon 1998). However, the Corps has demonstrated that the large renourishment projects have performed well, surviving hurricanes and major northeasters (Houston 1995, 1996a; Hillyer 1996; Stauble 1993; Stauble and Bass 1999) while providing storm protection to nearby communities (Hillyer et al. 2000) and providing a foundation for economic development (Houston 2002).

Beach-quality material that has been dredged from navigation channels, inlets, and harbors, may also be placed on adjacent beaches using Section 933 of PL 94-587. Sand can also be placed on the beach to mitigate sand loss caused by navigation projects, using Section 111 of PL 90-483. In the future, the Corps will seek to place most beach-quality sand removed from coastal inlets somewhere on the adjacent beaches or nearshore zone as long as the sand is compatible, does not contain contaminants or organic components, and costs are not excessive.

The Federal government has also placed sand on beaches on an emergency basis in response to serious erosion caused by major storms. Examples of this mechanism include emergency placements made after the 1962 Ash Wednesday storm and after the severe winter storm season of 1992 - 1993 (Hillyer 1996). Hurricanes have caused some of our most costly natural disasters (Table 4), and it is likely that the Federal government will be called upon to participate in more emergency recovery and beach nourishment efforts after future disasters.

### Table 4: Damage Estimates for U.S. Catastrophes

| Date | Event (Region of Greatest Influence) | Hurricane Category | Insured loss U.S. $ (millions)[1] | Total Damage estimate $ (millions)[1] | Total Damage in 2000 $ (millions)[2] |
|---|---|---|---|---|---|
| Sep 11, 2001 | World Trade Center & Pentagon terrorism | | > 38,000 | >80,000 | |
| Aug 1992 | Hurricane Andrew (Florida, Louisiana) [3] | 5 | 15,500 | 26,500 | 34,955 |
| Jan 1994 | Northridge, California, earthquake | | 12,500 | > 20,000 | |
| Sep 1989 | Hurricane Hugo (South Carolina) | 4 | 4,195 | 7,000 | 9,740 |
| Jan 1998 | Ice storms (NE USA, SE Canada) | | ~4,000 | | |
| Jun 2001 | Tropical storm Allison (Texas, eastern states) | | 3,150 | 4,880 | |
| Sep 1998 | Hurricane Georges (Virgin Is, Puerto Rico) | 3 | 2,900 | 3,600 | 3,888 |
| Oct 1995 | Hurricane Opal (Florida, Alabama) | 3 | 2,100 | 3,000 | 3,521 |
| Sep 1999 | Hurricane Floyd (mid-Atlantic, NE USA) | 2 | 1,960 | 4,500 | 4,667 |
| Mar 1993 | "Storm of the Century" (20 eastern states) | | 1,750 | 6,000 | |
| Aug 1969 | Hurricane Camille (Mississippi, Louisiana) | 5 | | 1,420 | 6,992 |
| Oct 1991 | Oakland Hills (Diablo Canyon), California, fire | | 1,700 | | |
| Sep 1996 | Hurricane Fran (North Carolina) | 3 | 1,600 | 3,200 | 3,670 |
| Sep 1992 | Hurricane Iniki (Hawaiian Islands) | - | 1,600 | 1,800 | 2,191 |
| Oct 1989 | Loma Prieta, California, earthquake | | > 960 | 7,000 | |
| Dec 1983 | Winter storms, 41 eastern U.S. states | | 880 | | |
| Apr-May 1992 | Los Angeles riots | | 775 | | |
| Apr 1992 | Wind, hail, tornadoes, floods (Texas, Oklahoma) | | 760 | | |
| Aug 1972 | Hurricane & tropical storm Agnes (Florida, NE USA) | 1 | | 2,100 | 8,602 |
| Sep 1979 | Hurricane Frederic (Mississippi, Alabama) | 3 | 753 | 2,300 | 4,965 |
| Aug 1983 | Hurricane Alicia | 3 | 676 | 2,000 | 3,422 |
| Sep 1960 | Hurricane Donna (south Florida) | 4 | 300 | 387 | 2,408 |
| Sep 1938 | Great New England Hurricane (Long Island, Rhode Island, Connecticut, Massachusetts) | 3 | > 300 | > 306 | > 4,750 |

**Notes:**

[1] Total damage costs exceed insurance values because municipal structures like roads are not insured. Sources: Insurance Information Institute, New York, NY (www.iii.org); *The New York Times,* December 28, 1993, citing insurance industry and State of Florida sources; *Daytona Beach News-Journal* web edition, 12 June 1998; *Forbes*, 13 May, 2002.

[2] 2000 prices based on the U.S. Department of Commerce Implicit Price Deflator for Construction. Note that many other prominent hurricanes have not been listed, such as Carol, Diane, Hazel, 1900 Galveston, 1926 Florida, and 1935 Florida. Source: Jarrell, Mayfield, and Rappaport 2001 (*The Deadliest, Costliest, and Most Intense United States Hurricanes from 1900 to 2000 (And Other Frequently Requested Hurricane Facts)*, NOAA Technical Memorandum NWS TPC-1 (available online at http://www.aoml.noaa.gov/hrd/Landsea/deadly/index.html, 20 Dec 2002)).

[3] Andrew, recently upgraded to Category 5, caused unprecedented property damage in south central Florida, when sub-standard structures were torn apart by the storm's winds. This demonstrates that hurricanes are not merely coastal hazards, although coastal residents usually are at greatest risk because of the danger from storm surges.

# REGIONAL DEMOGRAPHIC AND COMMERCIAL TRENDS

### *Historical background*

Numerous cultural and economic trends have influenced development of the coast and, therefore, the location of ports, channels, and shore-protection projects. Some of these factors include:

- Development of coastal areas, especially barrier islands, for recreation and vacation homes
- Locations of natural ports (originally not requiring much maintenance)
- Access to sources of raw materials (e.g., iron ore, minerals, and coal in the Great Lakes; grain in the Great Lakes and Galveston; timber in the Pacific Northwest; petroleum in the Gulf of Mexico; coal in Norfolk)
- Proximity to industrial base (heavy industry in the Great Lakes; refineries in southern California and the Gulf of Mexico; manufacturing centers along the Atlantic in the 1800's)
- Access to fishing grounds (New England) and the rest of the Atlantic seaboard
- Access to European markets for trade, immigration (New England, Atlantic seaboard)

During the early history of the nation, Boston, New York, Philadelphia, Baltimore, Norfolk, Charleston, and Savannah became centers of commerce, banking, and culture because their naturally-deep and wide harbors were suitable for sailing vessels. From the mid-late 1800's, ports on the Great Lakes grew as the industrial boom that followed the Civil War and the spread of railroads across the Midwest brought grain, iron ore, coal, and industrial products to the Lakes, turning Chicago, Duluth-Superior, Lorain, Toledo, and Buffalo into major ports. In the Pacific Northwest, timber trade with the Orient greatly increased ship traffic to Portland, Seattle, Grays Harbor, and many smaller towns. Timber trade with South America made Mobile a major timber port. Boston, Portsmouth (New Hampshire), and Portland (Maine) became major ice-export ports, with ice being shipped on sailing vessels as far as Buenos Aires.

Economic and technological changes during the 20th century shifted the types of cargoes passing through U.S. ports. For example, by the end of the 1930's, artificial ice production totally superseded the need for ice harvested from New England lakes (the ability to produce ice also eliminated the need for salt in food preservation [Kurlansky 2002]). Since the 1960's, the Northwest timber trade has diminished, but it has been partly replaced with grain, petroleum, and manufactured goods. The traditional east coast harbors still carry significant commerce, but the bulk of U.S. tonnage (petroleum) now passes through Gulf Coast ports. Container vessels now carry most manufactured goods and machinery, and New York, Norfolk, Miami, Galveston, Los Angeles-Long Beach, and Seattle have become major container ports. In the 1960's, the modern jet plane took over the role of moving passengers to and from Europe. As a result, few steamship passengers now embark at New York and Boston, but Miami and Port Everglades have become major cruise ship terminals.

Today, more than 80 percent of the U.S. population lives within 80 km of the coast (Fletcher et al. 2000). Some 673 coastal counties (defined as located totally or partially in coastal watersheds) account for 17 percent of the land area of the contiguous United States (Culliton 1998). The following paragraphs, based on Culliton et al. (1990) summarize characteristics of five coastal regions.

### *Northeast Atlantic States*

The Northeast is the most populated region of the United States, containing 18 of the 25 most densely-populated counties in the nation as well as the crowded urban concentrations of Boston, Providence, Bridgeport, New York, Philadelphia, Baltimore, and Washington. All of the northeast states (except Vermont) have the bulk of their populations - 63 percent - in the narrow band of coastal counties that border the ocean and estuaries. The coastal population is expected to increase 30 percent between 1960 and 2010. The greatest growth occurred during the 1960's, as an increasing mobile and prosperous postwar generation moved to the suburbs, aided by parkways and interstate highways and cheap oil. Future growth will make many environmental problems more serious given the urbanization and degraded environmental conditions that already exist in the Northeast. The counties with the largest projected population increases are suburbs of large cities (Table 5).

The aging US population will heavily influence future population changes in the northeast. Four counties that are expected to grow rapidly are popular retirement and resort destinations: Virginia Beach,Virginia; Worcester, Maryland; Ocean, New Jersey; and Barnstable, Massachusetts.

### *Southeast Atlantic States (including Atlantic coast of Florida)*

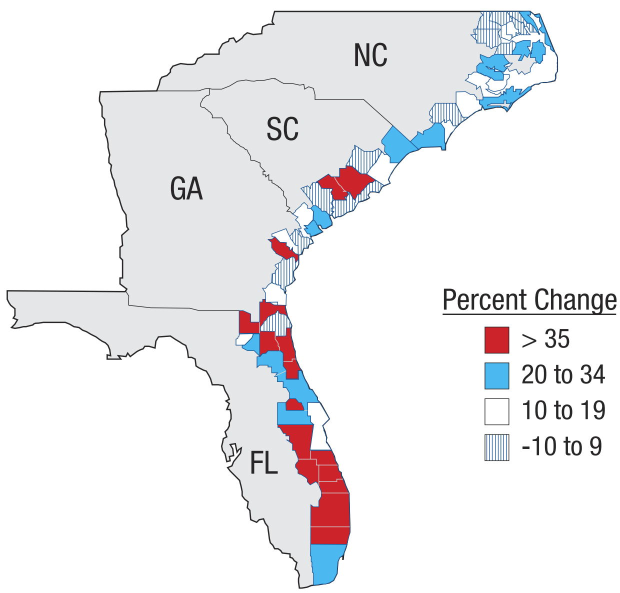
In 1988, coastal counties comprised only 19 percent of the land area of the southeast states, but these counties contained greater than 31 percent of the population. About 80 percent of the people in the southeast United States lived along the Atlantic coast of Florida. Overall, the population of the Southeast is expected to increase 180 percent between 1960 and 2010,

**Table 5: Counties with Greatest Projected Population Increases, 1988 – 2010**

| Northeast Atlantic | Southeast Atlantic | Gulf of Mexico | Pacific |
|---|---|---|---|
| **New York:** | **Florida:** | **Texas:** | **California:** |
| Suffolk | Broward | Harris | Los Angeles |
| Queens Co. | Dade | Fort Bend | Orange |
| **Virginia:** | Palm Beach | **Florida:** | San Diego |
| Fairfax | Seminole | Pinellas | Santa Clara |
| **Massachusetts:** | Orange | Pasco | Alameda |
| Middlesex | Volusia | Lee | Ventura |
| Plymouth | Brevard | Hillsborough | Sacramento |

Source: Culliton et al. 1990

**FIGURE 17** — *Projected population growth,1988-2010, Southeast U.S. (source: Culliton, et al. 1990). The greatest growth will be along Florida's east coast south of Cape Canaveral.*



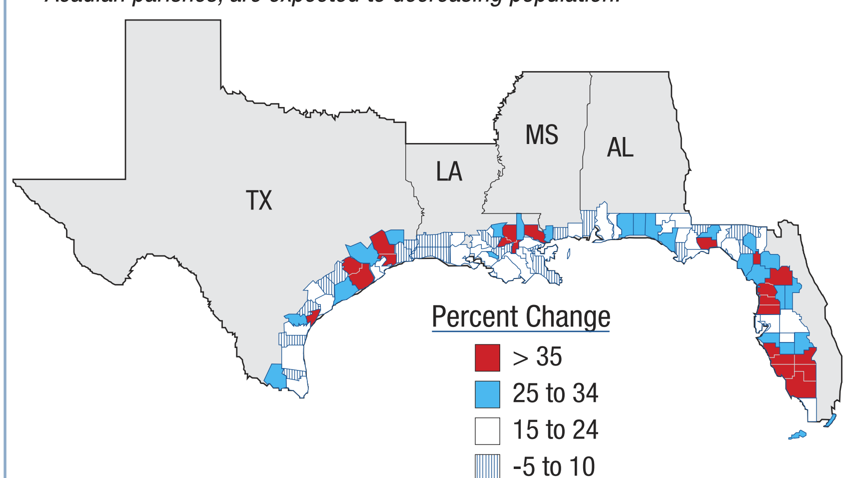

with eastern Florida growing 230 percent over these same 50 years (Figure 17). Although Florida has a large amount of agricultural and forest land, its economy is now dominated by marine activities and tourism. Over75 percent of Florida's residents live in coastal counties, and, in 1995, more than 60 percent of them were within 8 km of the water. Beaches contributed more than \$16 billion (\$16 x $10^9$) annually to the state's economy and created an estimated 780,000 jobs in 1996 (Schmidt and Woodruff 1999). Miami is a major port servicing the cruise industry and shipments of grain, machinery, and foodstuffs to Latin America.

Seasonal variations in population in the form of summer tourism occur in many low-density counties in coastal North and South Carolina, Florida, and Alabama. Population increases during the tourist season cause increased environmental stress from housing, hotels, recreation, and sewage waste, and the infrastructure and development is vulnerable to storm damage year-round. Many of the barrier shores in the Carolinas include parks and wildlife areas that will limit coastal development, but these areas may still require beach renourishment or other shore protection measures, depending on the storm climate, sediment supply, and other conditions.

### *Gulf of Mexico States (including west coast of Florida)*

In 1988, the Gulf states contained 13 percent of the U.S. coastal population, about 14 million. This is projected to grow to 22 percent of the U.S. coastal population by 2010 (18 million), the 2nd fastest growth of the five U.S. regions. The 50-year projected trend is for the coastal population to increase 144 percent between 1960 and 2010. The greatest growth occurred between 1970 and 1980, coinciding with the post-1973 oil shock, when Houston, Galveston, and many smaller towns boomed as they served the oil industry. This is also a period when tourists "discovered" the Florida Panhandle and the Alabama shore,

**FIGURE 18** — *Projected population growth, 1988-2010, Gulf of Mexico States (source: Culliton, et al. 1990). Portions of southern Louisiana, the Acadian parishes, are expected to decreasing population.*



and formerly sleepy fishing towns like Destin and Gulf Shores were frantically developed with condominiums and resorts. This development continues to this day, and stretches of the Gulf coast between Mobile Bay and Panama City are now essentially urban.

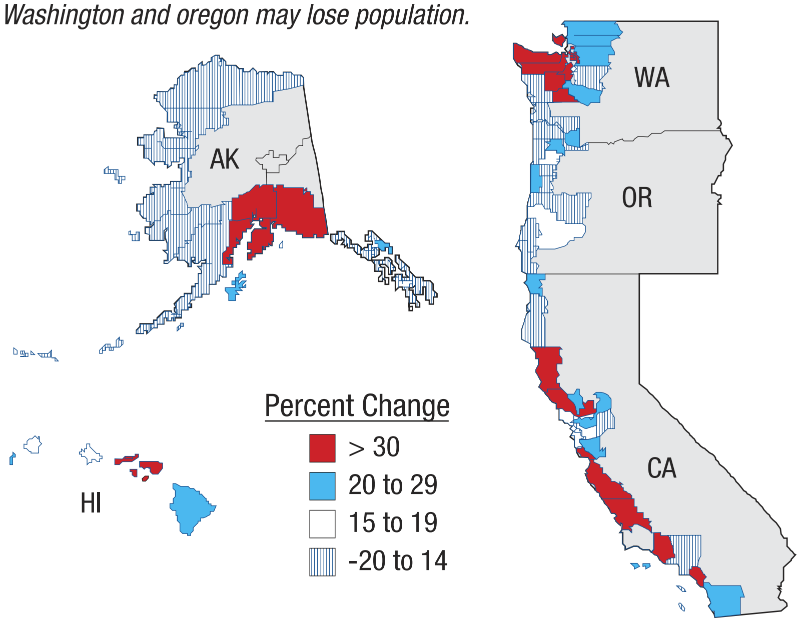
West Florida has been and will continue to be the greatest growth area, followed by Texas. Louisiana and Alabama will grow at a slower rate, and some areas of coastal Louisiana may lose population. With the collapse in oil prices in the mid-1980's and the abrupt decrease in offshore drilling and development, many small Louisiana towns suffered economic hardships. This was partially offset by immigrants from Vietnam who settled in Gulf towns to engage in fishing. Mississippi's Gulf Coast saw rapid development following legalization of casino gambling in the mid-1990's. Although coastal populations are increasing rapidly in the region, Gulf coastal counties are not expected to be as densely populated as many counties in the Northeast, the Great Lakes, or the Pacific.

## *Pacific States (including Alaska and Hawaii)*

In 1988, 29 million inhabitants lived in 77 coastal counties, with 77 percent of these in California alone. By 2010, the coastal population in the Pacific region is projected to increase 22 percent to more than 35 million. The leading growth counties will all be in California (Table 5; Figure 18). The value of beaches to California's economy cannot be understated. For example, in 1998, California's beaches generated $14 billion in direct revenue, while combining direct and indirect benefits amounted to a $73 billion contribution to the economy (King 1999). The same study of California's beaches estimated that the revenues generated 883,000 jobs.

Overall, the rate of growth in the Pacific coastal counties will be greater than in the Northeast and Great Lakes but less than the Southeast Atlantic and the Gulf of Mexico (Figure 19). The greatest population increases occurred in the 1960's. Alaska's almost doubled, while the other states increased 17 - 28 percent. Growth slowed considerably in the 1970's and increased again in the 1980's. The lowest growth rate was projected for coastal Oregon, possibly due to statewide no-growth policies in the 1980's and a decrease in logging and fishing. However, these predictions may have to be revised because the software and computer boom in Portland during the late-1990's provided the means for many urban residents to

**FIGURE 19** — *Projected population growth, 1988-2010, Pacific States (source: Culliton, et al. 1990). Much of coastal Alaska and parts of Washington and oregon may lose population.*



seek vacation homes on the coast. In the same way, prosperity in Seattle (and clever marketing in California) has spawned a construction boom on the Pacific coast near Greys Harbor.

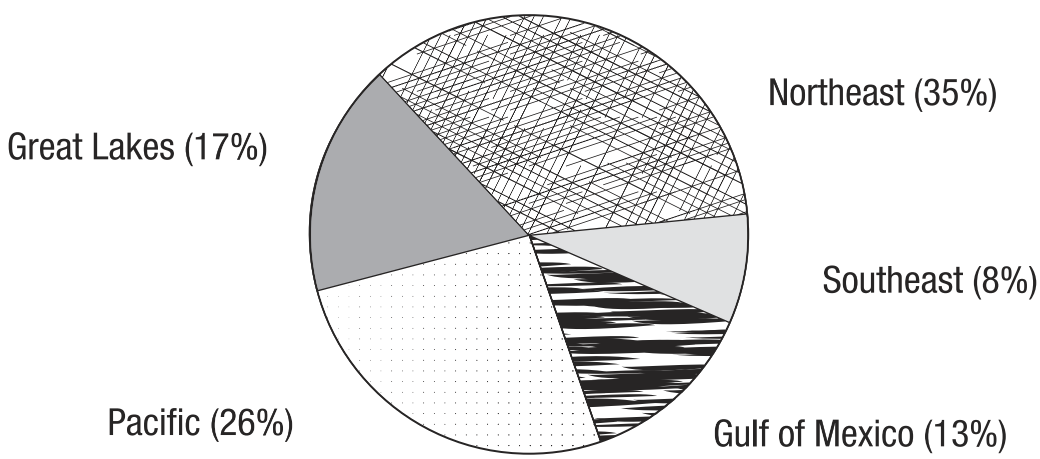
### *Great Lakes*

The Great Lakes is the third most populated coastal region of the United States, and includes the urban areas of Chicago, Gary, Milwaukee, Detroit, Toledo, Cleveland and Buffalo. However, the area also features parks and sparsely-occupied terrain along the Lake Superior shore. The coastal counties contain about 19 million people, 17 percent of the U.S. total. This region's share of the U.S. population is expected to drop over the next two decades because of relatively slow economic growth in most counties. The coastal population will only grow about 8 percent, less than the U.S. average.

### *Summary*

The Northeast still has the largest proportion of the nation's coastal residents (Figure 20), but since the 1960's, there has been a progressive shift in population toward the southeast states, especially to Florida, and to southern California. The leading states in absolute growth between 1960 and 2010 are predicted to be California (>19 million), Texas (12), and Florida (>11). Florida's coastal population is expected to grow more than 50 percent from 1990 to 2020 (Schmidt and Woodruff 1999), and the coastal counties of central and southern California will grow more than 30 percent from 1988 to 2010 (Culliton, et al. 1990). Despite environmental and development regulations, increasing populations will impose severe pressure on coastal environments and resources, and unexpected events, like hurricanes, may cause catastrophic damage under certain circumstances.

**FIGURE 20 — Distribution of the U.S. Coastal Population, 1990 (Source: Culliton, et al. 1990)**



# CONCLUSION

During the early years of the 21st century, a rapid increase in population and economic activity in the United States coastal states will cause tremendous development pressures in the coastal zone. Experience from early years of the 20th century clearly demonstrates the dangers of allowing uncontrolled and haphazard growth in vulnerable coastal areas. During the last 25 years of coastal zone management, the Federal government has largely preached a philosophy of retreat, but instead, development has only increased. It is naive to expect that coastal residents are going to retreat from their valuable property, except possibly in limited areas that are especially vulnerable, such as near inlets (Lenček and Bosker 1998). This means that in the future, the Federal government is likely to play an increasing role in infrastructure projects, coastal management, and environmental restoration, along with continuing its more traditional missions of navigation and flood protection.

### *Trends and Implications*

- **Maintaining Ports and Protecting Coastal Infrastructure**

  In Fiscal Year 2000, Corps and contractor dredges removed 218 million $m^3$ of material from federal-constructed and maintained channels at a cost of $821.6 million. Where the Federal and state regulations allowed, sand was placed in the nearshore zone if economically justified. Dredged material is a valuable resource with numerous potential benefits, including construction of protective dunes and beaches, maintenance of beaches through bypassing to reestablish natural sediment-transport paths, and restoration and creation of wetlands and coastal habitat. Demand for dredged material usage is increasing, but environmental concerns and constraints present new engineering challenges that must be addressed, as well as cost-sharing issues.

- **Protection and Renourishment of Beaches**

  Erosion and flooding threaten an estimated $3 trillion of development along the coast, with 80 to 90 percent of the nation's sandy beaches eroding. Shore protection and restoration throughout the developed areas of the coast will increase, especially if the growing value of coastal property and of recreation benefits are factored into the cost benefit calculations. Many coastal areas of New York, Florida, the Carolinas, and California already suffer from sand deficits and over-development, yet most coastal residents and tourists want expansive, sandy beaches conveniently available for recreation. In addition, new residents and visitors also expect to be supplied with the same infrastructure, roads, shops, and communications that they enjoy in the city. Compared to several other industrial nations, shore protection and restoration in the United States has been funded at remarkably low levels relative to the great economic importance of beaches (Houston, 1995). Travel and tourism to beach areas are critical to the U.S. economy, creation of jobs, and American competitiveness in a world economy (Houston 1996b, 2002).

- **Balancing Development and Stewardship of Coastal Resources**

  Because of the age of many harbor structures, improving and rebuilding jetties and breakwaters will become a significant infrastructure management need. Demand for wetlands, estuaries, and coastal haabitat restoration should also continue to increase.

- **Emergency Preparedness and Response**

  Emergency coastal response work is also likely to increase in the future. Many of the recent arrivals to the coast have not personally experienced a major disaster like the Galveston hurricane of 1900, the 1962 Ash Wednesday storm, or the Great New England Hurricane of 1938. Much of this population is blissfully ignorant of the hazards that exist and is not prepared to respond to the aftermath of a catastrophic storm. As technology and understanding of oceanography and coastal processes improve, future emergency response will involve using real-time data on waves and water levels as they occur in storms, hurricanes, and northeasters and translating the information into ways that can be directly used by emergency managers who have the mission of protecting the populations that have moved to the coast.

- **Need for System Approaches and Collaboration Among Federal, State, and Local Agencies**

  More government agencies are becoming involved in the coastal zone as coastal resources issues increase in importance. At the same time, legislation related to coastal issues is proliferating. As a result, substantial inconsistencies among agency programs abound. And finally, the interrelationships between processes in different parts of the coastal zone from estuaries to the open coastal shores are coming to the fore. All of this points to the need for a system-wide approach and collaboration among the myriad agencies in decisions relating to managing of coastal resources.

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The United States Army Corps of Engineers (Corps) has a demanding mission in building and maintaining civil works projects along the coasts and in inland waters of the United States. This mission includes maintaining deep-draft and recreation navigation into harbors and waterways, building projects for coastal storm protection and flood damage reduction, and environmental protection and restoration programs. These projects are based on or influenced by a number of factors, including:

(1) Historical settlement and development patterns;
(2) Geographical and geological conditions that vary regionally;
(3) Increasing pressures of a growing population that inhabits the coasts;
(4) Economic factors, such as the fundamental need to maintain navigable ports and waterways.

All demographic data point to the fact that the U.S. coastal population will continue to grow. Accordingly, that there will be continued demand for infrastructure improvement, storm protection, recreation development, and environmental restoration in the coastal zone. With respect to economic conditions, our growing dependence on imported petroleum products means that many ports, especially in the Gulf of Mexico area, will have to be improved to accommodate larger ships. The result will be increased dredging to deepen and maintain the channels.

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